# A comparative study of three commonly used two-dimensional overlay generation methods in bite mark analysis

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**Abstract**

**Aim:** The present study attempts to compare the bite mark overlays generated by three different methods. The objectives of the study were to compare the three commonly used techniques for overlay generation and to evaluate the interobserver reliability in assessing bite marks by these methods.

**Materials and Methods:** Overlays were produced from the biting surfaces of six upper and six lower anterior teeth of 30 dental study models using the following three methods: (a) Hand tracing from wax impressions, (b) radiopaque impression method and (c) computer-based method.

**Results:** The computer-based method was found to be the most accurate method. Of the two hand tracing methods, radiopaque wax impression method was better than the wax impression method for overlay generation.

**Conclusions:** It is recommended that forensic odontologists use computerized method, but the use of hand tracing overlays in bite mark comparison cases using radiopaque wax impression method can also be done where sophisticated software and trained persons in forensic odontology are not available.

**Keywords:** Bite marks, computer-assisted method, overlay generation methods, overlays

## INTRODUCTION

The professional obligation of a dental surgeon is not only to serve in diagnosis and treatment of oral and orofacial lesions but also serve in other community services and legal matters as well. Crime rates are rising and in almost every situation, there is a pressing need to identify the victims and identify the criminal. Forensic odontology is one of the revolutionary branches that have led to easy and accurate human identification.[1] It is not only helpful in the identification of the unknown deceased people, but it is also essential for the identification of living individuals who are missing and of culprits who try to hide their identity.

It is well said that "Criminals can lie through their teeth, but their teeth rarely lie!" Bite marks being unique to every person can be used by the forensic odontologist to hunt

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for the suspect or criminal. It has been defined as a pattern produced by human or animal dentitions and associated structures in any substance capable of being marked by these means.[2] The quality and accuracy of a bite mark depend on numerous factors, including time-dependent changes, where the bite mark was found, damage on soft tissue, dental similarity among individuals, and poor photography, impressions or measurements.[3] The bite marks are used to confirm or eliminate the identity of a suspect in relation to the bite mark, i.e., comparison of a known person's dentition to a patterned injury which appears consistent with a bite mark.

For analysis of bite marks, various techniques have been used from the older handmade overlay generation techniques to modern computerized methods. Overlays are nothing but tooth exemplars when biting surface data is transferred to clear acetate. It can be created by number of methods, like the impression making and hand tracing from dental study cast, photography method, photocopying method and computer-assisted methods of overlay generation.[4] We compared the three commonly used techniques which are readily available.

### Aim

The aim of the study is to compare three commonly used two-dimensional overlay generation methods in bite mark analysis.

### Objectives

1. To compare the three commonly used techniques for overlay generation
   a. Hand tracing from wax impression method
   b. Radiopaque wax impression method
   c. Computer-assisted method.
2. To evaluate the interobserver reliability in assessing bite marks by these methods.

### MATERIALS AND METHODS

A single-blind analytical study was carried out in the Department of Oral Medicine and Radiology in VSPM Dental College and Research center. Thirty dental study models which were already present in the Department of Prosthodontics were used for the study.

For each dental model three sets of overlays (i.e., total 90 overlays) were made by three different techniques as follows:
1. Hand tracing from wax impression method: The study casts were pressed on a single wafer of modeling wax sheet to produce shallow impression of the biting surfaces of the six upper and lower anterior teeth. A sheet of transparency film was placed over the wax sheet, and

the perimeter of each of the shallow depressions was hand traced using fine-tipped black pen [Figure 1]
2. Radiopaque wax impression method: The shallow impressions of the biting surfaces of anterior teeth were produced as described by hand tracing from wax impression method. A radiopaque restorative material, i.e. zinc oxide eugenol was sequentially added to the individual tooth impressions. A radiographic image was produced on an intraoral dental X-ray film (Kodak E speed) using dental X-ray machine at 70 Kvp, 10 mA at 0.2 s by allowing the central ray directed at 90° to the wax sheet surface. The film was processed. The bite marks were seen as white marks in a dark black background. The radiographic image was then similarly traced on a transparent sheet [Figure 2]
3. Computer-assisted method: The study models were scanned with the biting edges of the dental model over the glass plate of the scanner. The images were opened in Adobe Photoshop CS3 software. Then, a gradual selection of biting edges of the teeth was done using magic wand selection tool so as to obtain outlines of the biting edges. The images obtained were printed on transparent sheet [Figure 3].

Overlays obtained by these three methods were grouped as follows:
- Group A – The overlay generated by wax impression method
- Group B – The overlay degenerated by radiopaque wax impression method
- Group C – The overlay generated by computer-assisted method.

Three observers included in the study were:
1. First observer was postgraduate student from the Department of Oral Medicine and Radiology
2. Second observer was senior lecturer in the Department of Oral Medicine and Radiology
3. Third was a forensic odontologist.
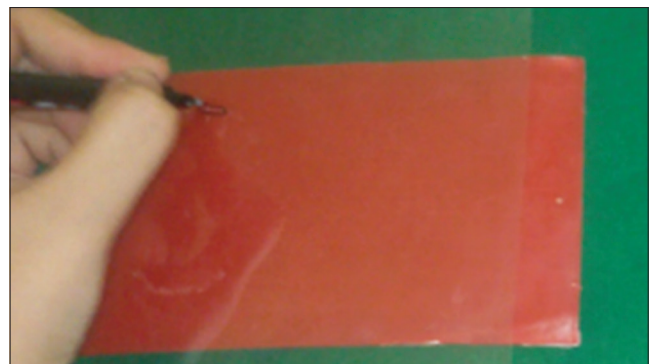


**Figure 1:** Tracing of biting edges in wax impression method

All the cast and the overlays were shuffled and then submitted to the three observers. The observers were given 6 criteria to choose the most appropriate matching. These are:

1. Width, thickness and spacing of the edges of the anterior teeth
2. Intercanine distance
3. Rotational position of teeth
4. Labiolingual position of teeth
5. Evidence of tooth out of alignment in the arch
6. Curves of biting edges.

The overlays obtained by each method were placed directly over the biting edges of the dental cast by observers for matching [Figure 4]. If four or more criteria were matching, it was considered to be a correct match.

### RESULTS

The three different methods were analyzed using Kruskal Wallis ANOVA test for matching the criteria. The percentage of positive matching for wax impression method was 64.4%, for radiopaque wax impression method was 74.4% and for the computer-assisted method was 81.1%, and this was found to be significant ($\chi^2$ = 6.453, $P$ = 0.0397) [Table 1].

Interobserver agreement for three different methods was analyzed using kappa statistics. Interobserver variation was highly significant for wax impression method ($P$ = 0.0012), significant for the radiopaque wax impression method ($P$ = 0.0418) and was not found to be significant for the computer-assisted method ($P$ = 0.5577). It suggests that in wax impression technique, the observers had less agreement and there was more interobserver variability [Table 2]. Third observer had better positive matching than the other two observers.

### DISCUSSION

In recent times, our nation is progressing with lightening speed but so is the crime rate, natural disasters and terrorist activities. In such a scenario, personal identification becomes essential both in case of living and dead people. Lip prints, fingerprints and DNA typing are some methods which are being conventionally used. However, they are highly technique sensitive, sophisticated, expensive and not readily available. Sometimes, bite marks are the only means of identification left. One of the most remarkable, difficult and sometimes troublesome challenges in forensic dentistry is the identification, recovery and analysis of the bite marks with the suspected biters.[5]
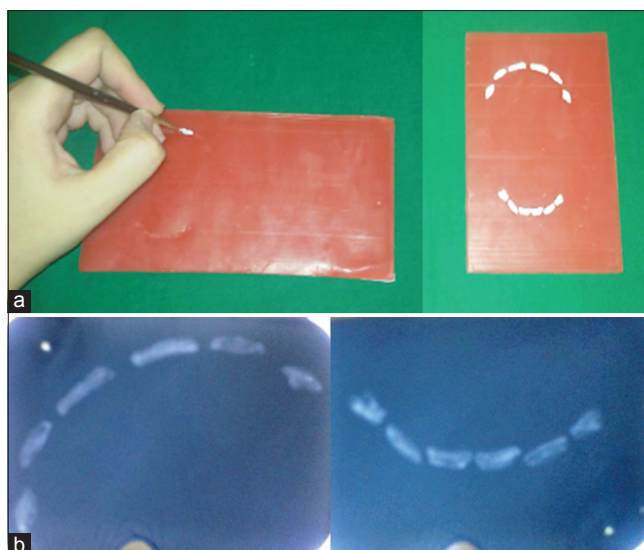


**Figure 2:** (a) Coating the bite marks using radiopaque material for radiopaque wax impression technique. (b) Radiographic image of bite marks
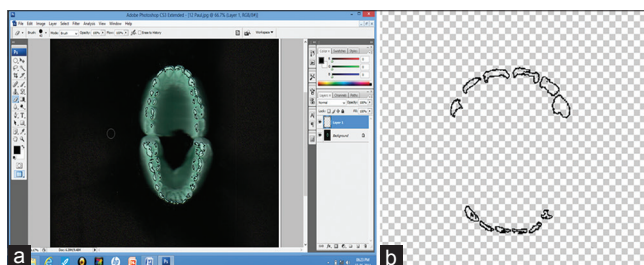


**Figure 3:** (a) Biting edges selected using magic wand tool in computer-assisted method. (b) Computer assisted overlay
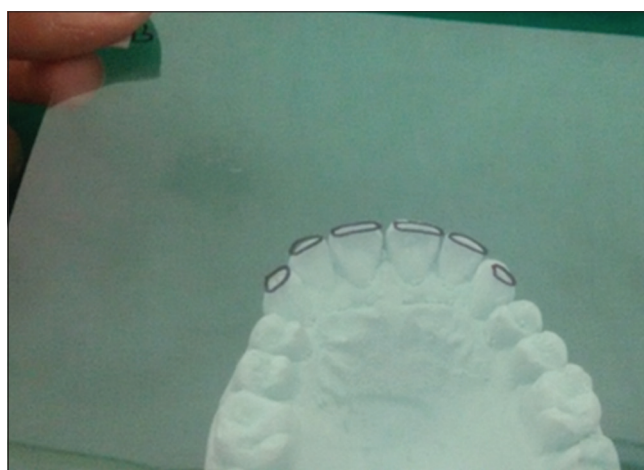


**Figure 4:** Matching the overlay

It is absolutely essential for the forensic odontologist to make use of the best available method for matching of bite marks, thus eliminating the subjective errors before presenting to the court of law. This study aimed to focus on bite mark overlay generation technique, as bite mark is a rising modality for suspect identification. Hence, we

**Table 1: Percentage of positive matching by three observers for three methods**

| Examiner | Wax impression technique, *n* (%) | Radiopaque wax impression method, *n* (%) | Computer-assisted method, *n* (%) |
|---|---|---|---|
| Observer 1 | 15 (50) | 17 (56.7) | 19 (63.3) |
| Observer 2 | 20 (66.7) | 24 (80) | 26 (86.7) |
| Observer 3 | 23 (76.7) | 26 (86.7) | 28 (93.3) |
| Average | 64.4 | 74.4 | 81.1 |
| Chi-square test | 1.7173 | 7.8261 | 9.718 |
| P | 0.424 (not significant) | 0.020 (significant) | 0.008 (highly significant) |

**Table 2: Kappa statistics for interobserver agreement in three different methods**

| Method | Kappa statistics | *Z* | *P* | Significance |
|---|---|---|---|---|
| Wax impression | 0.3211 | 3.05 | 0.0012 | Highly significant |
| Radiopaque | 0.1823 | 1.73 | 0.0418 | Significant |
| Computer | −0.0153 | 0.15 | 0.5577 | Not significant |

compared the three commonly used methods to find its reliability as a method for overlay generation.

Multiple studies[4,6-9] involving various techniques of bite mark analysis have been carried out for the past 50 years. Manual methods have been in practice since 1966, but Daily (1991) introduced the use of office photocopy machines to generate transparent overlays.[10] In 1998, Sweet and Bowers compared five methods which were in practice and stated that the computer generated overlay methods were superior to other methods, citing improved accuracy and objectivity.[7] Anne *et al*. in 2005 conducted a study to compare the reliability of two methods used to produce computer-generated bite mark overlays with Adobe Photoshop. One method was using magical wand selection tool while the other method is by inverting the glowing edges. It was concluded that both techniques were reliable methods to produce bite mark overlays in assessing tooth.[6] In the present study, the magic wand selection tool was used.

Recent studies[4,6,8] from the year 2011–2015 also found overlays generated by computer-assisted method to be superior than hand tracing methods. In 2011, Maloth and Ganapathy concluded that forensic odontologist could discontinue the use of hand tracing overlays in bite mark comparison cases as there is lot of scope for manipulation and observer bias.[4] In the most recent study by Jonathan Daniel in 2015 to validate different overlay generation methods, he concluded that computer-assisted method of overlay generation should be widely used for bite mark analysis in future as it is free from subjectivity incorporated in other techniques.[9]

In the present study also, three different techniques were analyzed and compared, but at the same time, we assessed the importance of observer knowledge to interpret the bite mark obtained from basic to modern techniques.

Although the computerized method was found to be the most accurate among the three, the radiopaque wax impression method was also found to be significantly useful. Thus, in areas where sophisticated software's are not readily available, the radiopaque wax impression method can be used. The computerized method was found to be the most accurate and also least interobserver variability among the three observers. On comparison of results of the three observers, better positive matching was seen in case of forensic odontologist (93.3%). Hence, we can thereby infer that even if the best method is available, the duration and clinical experience in forensic odontology is also necessary for proper bite mark analysis. Research is still ongoing to find the better technique as computer-assisted softwares can be easily manipulated.

The only limitation found in the computerized method is the power of manipulation. Forensic odontologist can manipulate the results which eventually lead to bias. In 2004, University of Granada, Spain developed new software package "Dental Print" that generates comparison overlays from three dimensional (3D) images of the suspect's dental cast.[11] This dental print software, however, is an important step forward in Forensic Sciences for bite mark analysis that generates different comparison overlays from 3D dental cast images. The procedure for generating comparison overlays is entirely automatic, thus avoiding observer bias.[11]

## CONCLUSIONS

Bite marks if analyzed properly not only can prove the participation of a particular person or persons in crime but also help in exoneration of the innocent. The field of bite mark science is continuing to develop, and so is the need for those who are trained and experienced in the identification with regard to the cases relating to the bite marks.

We conclude that in computerized method, subjective errors are comparatively less than in the hand tracing methods. Thus, computerized method is a more reliable method than the other two.

It is essential for the person examining the overlays to have knowledge about forensic bite marks analysis as the

final decision lies on the person to minimize errors in the analysis so as to facilitate a fair judgment.

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## Conflicts of interest
There are no conflicts of interest.

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